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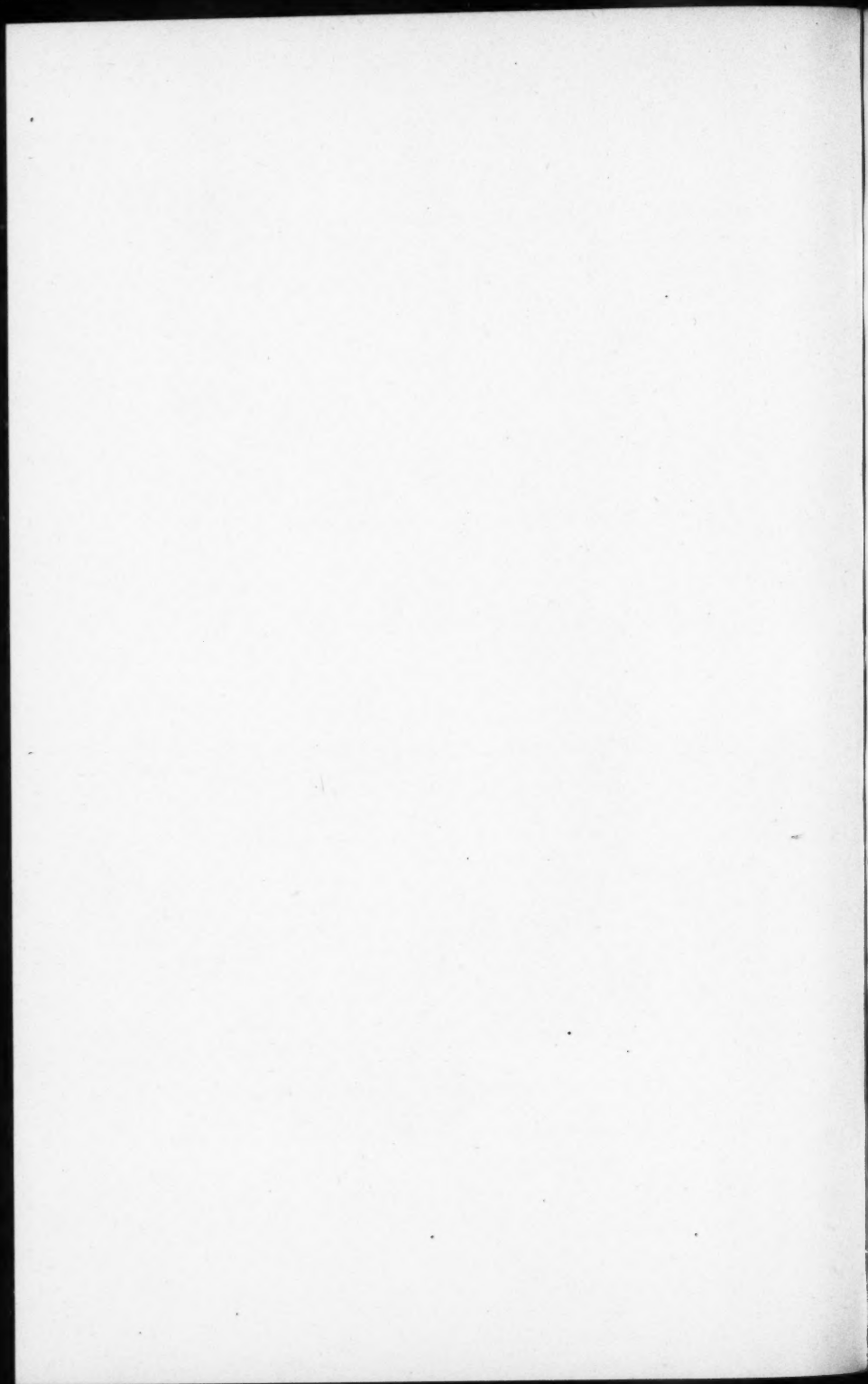
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PRESENTED BY SAMUEL HENSHAW.

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THE effect of the heavy tides in the Bay of Fundy upon the distribution of fishes in that region has been discussed by Dr. A. G. Huntsman (1918). He found that certain species of migratory fishes, whilst not being excluded from the Bay of Fundy, are unable to breed there successfully. All divisions of the marine fauna will naturally be exposed to the same influence and it only remains to follow up the question with reference to other orders. More than one circumstance lends interest to the investigation. Through the work of the Biological Stations at Woods Hole, Mass., a very complete knowledge has been obtained of the fauna of the Vineyard Sound Region to the south of Cape Cod which marks the position of the "Great Divide" between the boreal and temperate zones on the Atlantic coast of America. We have therefore an excellent standard of comparison at our disposal, and I have considered it worth while to emphasize the Arctic elements in our local marine fauna.

For some years, under the direction of Dr. Huntsman, plankton gatherings have been taken methodically at stations situated in and around Passamaquoddy Bay, in addition to outlying stations farther afield in the Gulf of St. Lawrence. Of these stations, one known as "Prince" Station 6 lies a little above the actual mouth of the St. Croix River, in the deep channel between the Biological Station near St. Andrews, N. B., and the settlement of Robbinston on the coast of Maine. In 1916-17, the plankton at this station showed exceptional features, particularly in the winter months, when there was a great demonstration of red oily *Calanus* constituting what I have elsewhere named a red macrocalanoid plankton. The result of the examination of this plankton, to which my attention was drawn by Dr. Huntsman, is the subject of the present note. In 1919-20 there was no such indraught of large calanoids, the winter plankton being sparse and microcalanoid.

The four species whose presence gives a special significance to the material comprise the largest of the free-living Copepods, namely, *Calanus finmarchicus*, *Calanus hyperboreus*, *Euchaeta norvegica*, and

Metridia longa. They are all more or less common constituents of the plankton in the Atlantic water where it mixes with the Labrador and Cabot currents to the southeast of Nova Scotia. Here the material obtained by the Canadian Fisheries Expedition under the direction of Dr. Johan Hjort (1914-15) contained many young and a fair admixture of adult females, both of *Euchaeta norvegica* and of *C. hyperboreus*, but very few adult males of *Euchaeta* and none of *C. hyperboreus*. Their zoogeographical character has been defined by C. W. S. Aurivillius (1898), *C. finmarchicus* being arctic and antarctic in the wide sense with far reaching adaptability to thermal changes, while the other three are arctic in the strict sense. Only the first-named (*C. finmarchicus*) figures in the list from Woods Hole. In the winter plankton of Passamaquoddy Bay (1914-15), McMurrich observed *C. hyperboreus* only in one gathering and then only as a single individual.

Passamaquoddy Bay is a branch of the Bay of Fundy which in its turn may be regarded, in its present configuration, as an arm of the Gulf of Maine. It is therefore necessary to refer briefly to the occurrence of the above-named species in the Gulf of Maine as determined by the explorations of the U. S. F. S. "Grampus" under the direction of Dr. Henry B. Bigelow. In the 1912 cruise of the "Grampus," *Metridia longa* did not appear in any gathering. Of 50 stations where *C. finmarchicus* occurred, *C. hyperboreus* was present twice only, one individual at station 40 and six examples amongst thousands of *C. finmarchicus* at station 23 (20-0 m.; Bigelow, 1914, p. 102). *Euchaeta norvegica*, a typical constituent of the deep water plankton of the Gulf of Maine, occurred in greatest abundance at station 43, where it formed the bulk of the haul in the closing net at 85 to 60 fathoms, its numbers equalling those of *C. finmarchicus*. At this depth (85-60 fathoms) the temperature was 42° F., and the salinity about 33.5‰.

In the 1913 cruise of the "Grampus," *Metridia longa* was recorded from several stations in the Gulf of Maine in small numbers. At station 10100, between Penobscot Bay and Cape Sable (*i. e.* opposite to the mouth of the Bay of Fundy), the quantitative haul (90-0 fathoms) registered 270 *C. hyperboreus* to 5400 *C. finmarchicus*. At this station *Euchaeta norvegica* was likewise abundant (Bigelow, 1915, p. 292).

In order to appreciate the contrast between the seasons 1916-17 and 1919-20, in Passamaquoddy Bay, it will be enough to consider two typical hauls at "Prince" station 6 in 1920, and then to present

the exhibits at the same station in 1916-17. On January 16, 1920 at 3.15 P.M., towing a net of No. 5 mesh at about 5 metres below the surface yielded 4 cc. of a microcalanoid plankton consisting mostly of young to submature copepods. So conspicuous was the paucity in adult individuals and so predominant was the genus *Acartia* that it might fittingly be designated a nepionic *Acartia* plankton. The following percentages were obtained, only the submature and mature *Acartia* being counted:—

<i>Acartia clausi</i>	68 per cent.
" <i>longiremis</i>	13 "
<i>Pseudocalanus elongatus</i>	16 "
<i>Temora longicornis</i>	3 " (juniors).

About the same date (January 27) in 1915, Professor McMurrich recorded a maximum of *Temora* at this station. Such fluctuations in the plankton are possibly correlated to some extent with the weir-catches of young herring, *Temora* being herring food *par excellence*, but there are no data at hand for proving this to be the case. On March 25, 1920, with the tow-net (No. 5) at about 7 metres, 6 cubic centimeters of an *Acartia*-*Balanus* plankton were obtained, *Balanus* larvae and Copepods occurring in subequal quantity. In addition there were a few *C. finmarchicus* from stage IV to adults of both sexes, two *C. hyperboreus* of stage IV, some *Pseudocalanus*, and a single example of *Monstrilla canadensis* McMurrich, dark brown in colour after preservation.

Turning to the winter of 1916-17, the catches are not strictly comparable with those of 1919-20, as they were taken at a different depth with a closing net (mesh No. 0) towed at 18-23 metres. On November 2, 1916, 64 cc. of a red macrocalanoid plankton were obtained, several *Sagittae* being present, but no fish eggs. One *Calanus hyperboreus*, stage V, was seen; one *Eurytemora herdmani* with ovisac, and one male *Metridia longa*. The remaining percentage content indicated a *Calanus*-*Tortanus* demonstration:—

<i>Calanus finmarchicus</i> V.....	46 per cent.
" " ♀.....	2 "
<i>Pseudocalanus elongatus</i>	5 "
<i>Temora longicornis</i>	1 "
<i>Tortanus discaudatus</i> (♂ and ♀).....	46 "

On December 8, 1916, the plankton had the same general appearance and was still more copious, amounting to 87 cc., with *Sagittae*

fairly plentiful. The species of *Sagitta* is *S. elegans* Verrill (Huntsman, 1919, p. 445). It should be mentioned that *Acartia* was present, but as it apparently passes readily through the meshes of the net employed, it does not appear in the records. One *Metridia longa* ♀, one *Temora longicornis* ♀, and one *C. finmarchicus* ♂ were seen. The percentage count showed predominance of *C. finmarchicus*, stage V:—

<i>C. finmarchicus</i> V	73 per cent.
" VI (adult)	9 "
<i>Pseudocalanus elongatus</i>	9 "
<i>Tortanus discaudatus</i>	9 "

The climax of this macrocalanoid intrusion was reached on February 23, 1917, though the quantity, 85 cc., was a little below that of December 8. Many large *Sagittae* were present. There was a sprinkling of large copepods, conspicuous amongst the rank and file composed of *C. finmarchicus*, but not in sufficient numerical strength to appear in the percentage estimation, so that in such a gathering as this, the count alone would fail to convey its most distinctive features. One characteristic however is not lost in the table, namely, the large number of male *C. finmarchicus*:—

<i>C. finmarchicus</i> V	36 per cent.
" ♀	27 "
" ♂	20 "
<i>Pseudocalanus elongatus</i> (♂ and ♀)	13 "
<i>Tortanus discaudatus</i> (♂ and ♀)	4 "

[There was a solitary larva of the Greenland sculpin, 8 mm. in length, identified by Dr. Huntsman].

In this setting of *C. finmarchicus* there was a scattering of *Metridia longa*, male and female, and, standing out boldly from the mass, *C. hyperboreus* and *Euchaeta norvegica*. The sample denotes the winter *Calanus maximum* for 1917 in Passamaquoddy Bay in the tidal channel of the St. Croix River.

On April 7 following, the mass of plankton (51 cc.) at station 6 consisted of a nearly pure culture of *Balanus nauplii* with *C. finmarchicus* (males, females and juniors) sprinkled sparsely through it. On May 1st, *Sagitta*, *Calanus*, and the comb-medusa (*Pleurobrachia*) were present, but the bulk (70 cc.) was pure *Balanus*, nauplii and cypris-larvae in subequal numbers, the latter somewhat more numerous and, being heavier, tending to collect in a layer at the bottom, the

whole sample presenting the appearance of millet seed. This was the spring *Balanus* maximum for 1917 at the same station where the *Calanus* maximum was celebrated earlier in the year. Finally on May 17, the surface tow at the same station yielded 7 cc. of plankton which, apart from some lighter material and few *Balanus* nauplii, consisted of cypris-larvae of *Balanus*. It should be added that this remarkable material was well known to Dr. Huntsman who kindly permitted me to examine it. A similar efflorescence has been noted by Professor Herdman in the Irish Sea. In 1907 the nauplii first appeared in the Bay at Port Erin on February 22, attaining their maximum on April 15, and disappearing on April 26. The cypris-larvae were first taken on April 6, rose to the maximum on the same day with the nauplii, and were last caught on May 24.

The males of *C. finmarchicus* formerly passed for extremely rare because they only appear in the upper layers at the epoch of reproduction in the spring (Damas 1905). In the spawning centres of *C. finmarchicus*, the eggs are stated by Damas to be sometimes so abundant that they constitute one of the principal elements in the plankton in certain regions, tens of millions in a sample, even to the exclusion of other forms. They float at variable depths down to 200 metres, but accumulate in the upper layers. Such spawning *en masse* has not been observed in Canadian waters nor in the Gulf of Maine which would seem to be the southern headquarters of *C. finmarchicus* in the northwestern Atlantic. O. Paulsen (1906) found *C. finmarchicus* propagating in Icelandic waters to the south of Iceland from March to June. C. W. S. Aurivillius (1898) states that males of *C. finmarchicus* were observed fairly generally in the deep water of the Gullmarfjord in the Skagerak in August and September 1897. It is to be presumed that they were derived from the spring spawning of that year in other waters.

From the examination of rich material collected by Norwegian and Danish vessels, Damas found that the distribution of the great mass of eggs of *C. finmarchicus* coincides with that of the maxima of frequency of the adults. The abundance is at its height in May and June in the waters of the Gulf Stream around the Faeroë Islands. The meeting of the waters which descend from the north, passing to the east of Jan Mayen island in the Greenland Sea, with the warm and salt Atlantic water, is the new factor which brings these individuals to the "ponte." The stations which traverse the Faeroë-Shetland Channel present a profusion of eggs, whilst a five minute surface tow with a metre net may collect more than a litre of Cope-

pods,—the best example of a monotypic plankton. Damas adds very pertinently that the determination of areas of reproduction is the first sure step in the study of marine productivity.

The males of *C. hyperboreus* have only been met with in comparatively recent years and there was no expectation that they would ever be found in the waters of the maritime provinces of Canada, because their proper province lies in high latitudes. According to Damas, the Copepod plankton of the blue water of the Polar Current to the northeast of Iceland is a *C. hyperboreus* plankton; that of the central part of the Norwegian sea is a *Pseudocalanus* plankton; that over the coastal banks of Norway is a *Temora* plankton; and the bathypelagic plankton of the Norwegian sea is a *Euchaeta* plankton. In the *C. hyperboreus* plankton of the Norwegian stations northeast of Iceland in May and June 1904, there was a majority of juniors, some females, but not one male. The absence of large eggs in the oviducts and of larvae in the sea, as well as the absence of males, showed that the species was not reproducing there at that season. In gatherings taken by Captain Amundsen near Francis Joseph Land, the great nauplius and the metanauplius of this species were found by Damas to abound in company with opaque females gravid with eggs and with some males which, as mentioned, were totally absent from the Icelandic plankton.

Nordgaard (1905) found males of *C. hyperboreus* in deep water in the Ofoten Fjord and vicinity (between 68° and 69° N. lat.) and concluded that the spawning season for this species in the northern fjords lies in the months of February, March and April. If this is so there must be two broods in the year. The captures were the following:

Date	Depth (m.)	Bottom (m.)	Females	Males
7 II, '99	300-350	360	74	8
"	200-250	258	25	1
17 II, '99	450-550	630	17	4
"	550-620	630	2	2
16 III, '99	400-500	640	6	2

Damas and Koefoed (1907) state that the spawning of *C. hyperboreus* was observed by Vanhöffen (1897) off the west coast of Greenland, but I have not had access to Vanhöffen's article and do not know whether he recorded the males. In the cruise of the "Belgica" promoted by

the Duc d'Orléans in the Greenland Sea (1905), Damas and Koefoed reported that the samples from stations 46, 47 and 48 were remarkable for the abundance of eggs and nauplii of *C. hyperboreus*, together with females whose oviducts were full of eggs, as well as some males which are elsewhere so rare. The following are the positions of the stations in questions:—

Station 46. Lat. 77° 29' N., Long. 18° 31' W.

Depth 265 metres; vertical haul 13–0 m.; Aug. 4, 1905.

Eggs and nauplii of *C. hyperboreus* in great quantity.

Station 47. Lat. 76° 47' N., Long. 15° 21' W.

Depth 180 metres; vertical haul 20–0 m.; Aug. 8, 1905.

Nauplii of *C. hyperboreus* in great quantity.

Station 48. Lat. 71° 22' 5 N., Long. 18° 58' W.

Depth 1130 metres; vertical haul 10–0 m.; Aug. 15, 1905.

Oviducts full of eggs; nauplii in great quantity.

It follows from Damas' researches that the two species, *C. finmarchicus* and *C. hyperboreus* reproduce principally at two extreme points of the basin of the Arctic Ocean, the former in the south, the latter in the north. Whilst they are often mixed in planktonic samples, the conditions of their reproduction are quite different.

From the February material of "Prince" station 6 (1917), I picked out 31 examples of *C. hyperboreus* distributed as follows:—

<i>C. hyperboreus</i> IV	6
" V	14
" ♀	5 (7.25 mm. long)
" ♂	6 (6.1 mm. long)

The adults of both sexes were new, transparent, freshly exuviated and turgid with pink oil. Whereas the many males of *C. finmarchicus* averaged a little over 3 mm. in length, the male *C. hyperboreus* somewhat exceeded 6 mm. and were proportionately bulky so that the contrast in size was most striking. The lateral corners of the last thoracic segment (*th 5*) of these new males was nearly rounded, at most very obtusely pointed, less pointed than it sometimes appears as a variation in *C. finmarchicus*, but the spinous armature of the outer branch of the left fifth foot and the coxal teeth of the fifth feet, together with the large size, proved beyond question that they were the males of *C. hyperboreus*. The large females which accompanied the males and were equally new and oily, showed the specific point at the lateral edge of *th 5*; and the coxal teeth of their fifth pair of feet were likewise those of *C. hyperboreus*.

Of the great red oily *Euchaeta norvegica*, the mature females of which measured up to 8 mm. in length, and the males a little more than 6 mm., 46 examples were observed, distributed as under:—

<i>Euchaeta norvegica</i>	♀	37	} "Prince" Station 6, February 23, 1917.
"	"	♂	4	
"	"	♂ (jun.)	4	
"	"	♀ (jun.)	1	

Some of the females were carrying an ovisac laden with eggs, others had a spermatophore attached to the genital segment, and two of the males each held a spermatophore by the cheliform extremity of the left fifth foot. The relatively large proportion of males is noticeable. During the Canadian Fisheries Expedition (1914-15) only six males were observed altogether at the stations of the C. G. S. "Acadia," southeast of Nova Scotia and only in one vertical haul as many as two were seen; the remainder were found singly.

A still greater proportion of *Euchaeta* males appeared in the stomach contents of the coal-fish (*Gadus* or *Pollachius virens*), locally known as the "pollack," taken off Wilson's Beach, Campobello Island, at the entrance to Passamaquoddy Bay on August 2-4, 1916. In the first one which I examined, the bulk of the contents consisted of the Schizopod, *Meganyctiphanes norvegica*; there were also some of the smaller species, *Rhoda* or *Thysanoëssa inermis*, some Caprellids, fish remains, several Sagittae, and 56 *Euchaeta*, namely:—

<i>Euchaeta norvegica</i>	♀	27
"	"	♂	7
"	"	V	22

Of the females, 4 retained the egg-sac.

Another "pollack" stomach was full of "red feed" consisting of a densely packed mass of *Euchaeta* mixed with an approximately equal quantity of Schizopod remains half digested. *Euchaeta* composed a moiety of the total content. One intact *Meganyctiphanes* was present. The following percentage of the Copepod content was made out very clearly:—

<i>Calanus finmarchicus</i>	V	1 per cent.
"	"	♀	1 "
"	"	♂	1 "
"	hyperboreus	V	2 "
"	"	♀	3 "

<i>Euchaeta norvegica</i>	IV	1 per cent.
“	“	V 56 “
“	“	♀ 20 “
“	“	♂ 14 “
<i>Metridia longa</i>		1 “

The high percentage of males of *Euchaeta* is a proportion not hitherto met with in the free plankton of this region, possibly owing to the fact that bottom-tows, *i.e.* with the net a little over the bottom in deep water, are not usually attempted at our stations. A tow at ten fathoms at an adjacent station ("Prince" station 1) off Eastport at the same time (August 2, 1916) yielded 54 cc. of plankton material from which the following Copepod count was made:—

<i>Calanus finmarchicus</i>	II	2	
“	“	III	8
“	“	IV	17
“	“	V	80
“	“	♀	8
“	“	♂	22
“	<i>hyperboreus</i>	IV	9
“	“	V	8
“	“	♀	3
<i>Pseudocalanus elongatus</i>			50
<i>Euchaeta norvegica</i>	V		5
“	“	♀	2
<i>Metridia longa</i>			12
“	<i>lucens</i>		4
Total counted			230

The excess of male *C. finmarchicus* in this gathering has no particular significance because the same station three weeks earlier (July 10th) yielded males and females in equal numbers. The individuals of stage V varied in length from 2.6 to 4.6 mm., and would be continually replenishing the stock of females.

The mere presence of the three Arctic species (*C. hyperboreus*, *E. norvegica*, and *M. longa*) in Passamaquoddy Bay is not unexpected but in our experience it is exceptional to find them extending in winter so far up the bay as to penetrate well within the mouth of the St. Croix river. Moreover the association of males and females of *C. hyperboreus*, although in a nascent state, adult in form but not

fully mature in sex, came as a surprise. I am indebted to Dr. Huntsman for the following hydrographic data relating to "Prince" station 6. It will be seen that they throw no fresh light upon the special biological features of the plankton:—

Date.	Depth (metres).	Temperature (C.).	Salinity (‰).
Nov. 2, 1916	20	8.69	31.62
Dec. 4, 1916	20	5.30	32.12
Feb. 23, 1917	20	-0.77	31.91
Mar. 28, 1917	20	1.32	31.64
May 1, 1917	20	2.50	30.05
Jan. 16, 1920	10	0.46	30.84
" "	30	0.67	31.44

Notwithstanding the negative evidence afforded by the hydrographic determinations, there is still a possibility that the somewhat extraordinary nature of the plankton samples taken off Robbinston at "Prince" station 6 during the winter of 1916-17 can be attributed ultimately to a remote flooding of Arctic water in the Labrador current from Baffin Bay, acting in conjunction with the Cabot current issuing from the Gulf of St. Lawrence and with the tides of the Bay of Fundy. Its proximate causation may have had a more local agency. It is certain that the individuals of *C. hyperboreus* and *Metridia longa* were not produced nor would they reproduce where they were found in the estuary of the St. Croix river, although the exuviation from stage V to stage VI may easily have occurred within our waters. If we may judge from their store of oil, they had thriven amazingly during their wanderings and would have had a good chance to avail themselves of reversed currents to regain their spawning area in the north. Failing this, they would presumably perish as stragglers without leaving descendants. Not only do they occur in the Baffin Bay region to the west of Greenland, but they attain their largest dimensions there (Aurivillius 1896). Both species were taken in the Dolphin and Union Strait by the Canadian Arctic Expedition.

In conclusion it cannot be pretended that our knowledge of the great northern currents, which is so essential in connection with fishery problems, is materially advanced by the present contribution. Its chief claim to consideration is the biological interest appertaining to the identification of the rare males of the hyperborean *Calanus* in comparatively shallow water a little above the forty-fifth parallel of latitude.

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- Willey, A.** Report on the Copepoda. Canadian Fisheries Expedition 1914-15, pp. 173-220, Ottawa, 1919. By an unfortunate inversion in Table IV, p. 208, *Calanus hyperboreus* has the male sign attached to it in error instead of the female sign.
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